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Lessons Learned from JTA Tester Safety Studies

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Abstract:

EP401575, Issue C, calls out a requirement to perform safety studies for testers that are used to accept Joint Test Assembly (JTA) product at Pantex. The underlying motivation is to ensure that personnel hazards due to inadvertent initiation of electro-explosive devices (EEDs) during JTA testing are understood and minimized. Studies have been performed on the B61-7/11 JTA, B61-3/4/10 JTA, B83 JTA, and W76 Type 2F testers at Pantex. Each of these studies includes an examination of the relevant Pantex tester as well as the instrumentation and War Reserve (WR) hardware. In performing these analyses, several themes have emerged that could be useful for the Phase 6.3 design efforts for the weapons, the associated instrumentation, and the JTA testers. This report summarizes the lessons learned from these studies.

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Acronyms

DOE	Department of Energy
EED	Electro-explosive device
EQ	Equipment Qualification
ESD	Electrostatic Discharge
IHE	Insensitive High Explosive
JTA	Joint Test Assembly
KCP	Kansas City Plant
MOV	Metal Oxide Varistor
NELA	Nuclear Explosive-Like Assembly
PX	Pantex
QE	Quality Evaluation
SNL	Sandia National Laboratories
SS	Safety Specification
WR	War Reserve

Lessons Learned from JTA Tester Safety Studies

Introduction

EP401575, Issue C, calls out a requirement to perform safety studies for testers that are used to accept Joint Test Assembly (JTA) product at Pantex (Reference 1). The underlying motivation is to ensure that personnel hazards due to inadvertent initiation of electro-explosive devices (EEDs) during JTA testing are understood and minimized. Studies have been performed on the B61-7/11 JTA, B61-3/4/10 JTA, B83 JTA, and W76 Type 2F testers at Pantex (References 2-5). Each of these studies includes an examination of the relevant Pantex tester as well as the instrumentation and War Reserve (WR) hardware. In performing these analyses, several themes have emerged that could be useful for the Phase 6.3 design efforts for the weapons, the associated instrumentation, and the JTA testers. This report summarizes the lessons learned from these studies.

Note that in some cases, the recommendations provided below to enhance safety during JTA testing operations (e.g., adding isolation resistors in the monitoring lines) may result in a reliability degradation or other surety impact. Thus it is important to consider these lessons learned in the context of the overall design and to make tradeoffs in light of the integrated surety objectives.

The lessons learned are listed in five different categories, as summarized below:

- Instrumentation considerations
- WR design considerations
- Tester considerations
- Administrative procedures during JTA assembly
- Administrative procedures prior to and during JTA testing.

The first three focus on minimizing the probability of inadvertent application of power to EED initiation lines due to component, connector, and assembly failures. The last two describe procedural steps that can be taken at Pantex to either minimize the risk (e.g., by ensuring that tester power supplies cannot supply excessive power to the unit under test) or to mitigate the consequences of unexpected EED initiation (e.g., by instructing test operators to avoid standing in areas where they could be at risk in the event of EED initiation).

Instrumentation Considerations

Below are listed instrumentation design approaches that have been used in the past that reduce the risk of inadvertent initiation of EEDs.

- Use current limiting resistors in the signal monitoring lines in the instrumentation, especially when monitoring EED initiation lines.
- Although not its intended function, the signal conditioning circuitry in the telemetry provides buffering for some types of faults.

- Assign connector pins in the instrumentation such that power lines are not adjacent to EED initiation lines.
- Consider potting the major components of the instrumentation. This may help prevent migration of foreign material that might be present in the assembly that could cause shorting between power and EED initiation lines.
- If power lines are adjacent to EED initiation lines within the instrumentation, perform tests before the EEDs are present to ensure isolation between power lines and EED initiation lines.

WR Design Considerations

There are several WR design practices that can aid in JTA testing safety.

- Use current limiting resistors within the WR system on monitoring lines going to the instrumentation (including EED initiation lines).
- Consider how the WR functional devices and safety features can be used to enhance safety during JTA testing operations. Devices such as strong-links and option select switches can provide important isolation between the instrumentation and the EEDs if the monitoring points are selected properly. For example, the WR system can be designed so the monitoring of WR lines is done with the instrumentation isolated from the actual EED initiation lines by a ready/safe switch until the switch is put in the “Safe” position. As a specific example, the B61-3/4/10 monitoring (where the ready/safe switch provides isolation during testing) should be contrasted with the B83, which does not take advantage of the isolation provided by the option select switch. Strong-links can be used to isolate the instrumentation from devices operated by the firing set. Note that for both of these cases there are tradeoffs to be made vis-à-vis defect detection, but safety should be one factor considered when deciding where to monitor.
- In some cases the WR strong-links cannot be used as described in the last paragraph to provide isolation, since lines within the firing set are directly monitored by the instrumentation; i.e., the (open) strong-link is not positioned between the instrumentation and the EED. For these cases, other elements of the strong-link design may offer protection. For example, the W76-0 strong-link provides a path between the firing set charging circuit and ground when the strong-link is open to ensure that voltage inadvertently applied via the instrumentation is shunted safely to ground.
- For cases where data collection must be done following a flight test in which the firing set has been charged, a combination of a firing set bleeder resistor and an adequate waiting time will mitigate the risk.
- Multiple use of the same connector to attach the instrumentation to the WR system should be avoided. This helps prevent incorrect assembly and possible misapplication of power. If

this isn't possible for some reason, explore other means (e.g., connector shell keying) to prevent incorrect connections. If this is impossible, consider the following options. Ensure that assembly procedures explicitly address the possibility of reversing the connectors. Review the pin layouts to seek ways to prevent application of energy that would be damaging; consider adding diode protection to lines when needed. Include test steps that explicitly check for correct connections and flag problems. Finally, ensure that checking connectors be done early in the trouble-shooting process if the instrumentation fails to operate.

- Design the instrumentation such that the grounding scheme for the WR and all JTA configurations is the same. This will prevent introducing problems as well as masking existing problems.

Tester Considerations

Tester designs have incorporated many of the elements below, which help to minimize the risk of inadvertent initiation of EEDs.

- Use multiple levels of testing of the JTA, where successive levels incorporate increasing amounts of WR hardware, including EEDs. To mitigate the increasing vulnerability, use a decreasing number of connections and inputs to the JTA, culminating in a single connector at the highest level of testing and using a very limited set of inputs from the tester. This approach allows for thorough testing of the telemetry hardware with minimal risk to the EEDs.
- Minimal stimuli should be provided by the tester to the instrumentation when EEDs are present in the test configuration. If EEDs are present, the stimuli should be reviewed for any risks they create to the EEDs.
- When continuity of EED initiation lines is checked, consider the use of a current-limited tester such as the PT4030.
- Surge suppression for the tester should be reviewed. Check for suppression at the substation, building, and tester level. Use Metal Oxide Varistors (MOVs) in the tester and check them every calibration cycle.
- Each of the power supplies used in the tester should be reviewed for voltage and current capability. Unneeded capabilities that may compromise safety should be eliminated.
- Some programmable power supplies (including the widely used HP 6032A) have the capability of programmable limits for voltage and current and a “foldback” capability, where the supply can detect and respond to abnormal conditions. These features should be understood and used for the testers.
- Current limits should be set such that unnecessary hazards are not introduced. Compare the current limit set during testing with the actual required current to make sure that it is not in

excess of what is needed for the JTA testing. This does not preclude a higher current limit being used for the non-safety critical configurations. Note that a lower current limit may actually assist in finding anomalies; if the power supply foldback option is used as suggested above, excessive current draw will be flagged by a shutdown of the power supply. Also, limiting the current in all cases to the lowest required level will minimize damage if there is an anomaly such that larger than expected current is drawn. In summary, it is recommended that the current limits be set to the lowest required level to perform the testing, with some nominal margin to prevent false alarms.

- A review of the relevant power supply set-up software should be performed during the tester Equipment Qualification (EQ) process to ensure that the tester power supplies are providing the correct voltage. The software should be reviewed again if it is subsequently changed.
- It would be advantageous to perform a detailed safety analysis of the tester power supply to identify possible single point failure modes resulting in excessive voltage or current.
- Consider the use of zener diodes to limit the voltage coming in on the power lines going from the tester to the unit. Additional protection circuitry external to the power supply could be added to provide independent current- and voltage-limiting (see Reference 6).
- Identification resistors (unique resistors placed between pins on a cable connector) should be included in the tester-to-unit cables to ensure proper hook-up; these should be checked when the testing begins, and testing should be aborted if the check fails
- The various tester cables should incorporate different connectors so the risk of mis-connecting is reduced.

Administrative Procedures During JTA Assembly

One of the main issues to be addressed during JTA assembly is that of electrostatic discharge (ESD). However, it is also important to verify that the WR and JTA features that aid in JTA tester safety are in place.

- ESD-sensitive devices should be identified by the design agency in a Safety Specification (SS) drawing. The ESD sensitivity of EEDs in both the WR and instrumentation should be determined and documented.
- The Pantex operating procedures should be reviewed to ensure that they address ESD precautions for the EEDs in a thorough manner. These procedures should be reviewed during the Quality Evaluation (QE) process, and it is important to ensure that future versions retain these precautions.
- During disassembly of the weapons returned from the stockpile, ensure that the position of the functional and safety switches are correct. For example, ready/safe switches should be

checked to make sure they are in the “Safe” position. Strong-links should be checked to make sure they are open.

- There are some JTA configurations that include insensitive high explosive (IHE). For the cases previously studied, the main detonators are present in the JTA and attached to the IHE, but not connected to the firing set in order to prevent inadvertent detonation of the IHE. It is recommended in such cases that the detonator cables be cut off such that it is physically impossible to have contact between the cables and firing set. If that is considered undesirable (due, perhaps, to a desire to surveil the detonator cables following the test), then review the procedures to ensure correct assembly of these configurations to prevent connection of the detonator cables to the firing set. It is recommended that a DOE inspection step be included in the assembly process in this case.
- For JTA configurations for which there could be severe consequences if inadvertent initiation occurred (e.g., those that include insensitive high explosive), assembly of units should be done in a different bay.

Administrative Procedures Prior to and During Testing

There are administrative procedures that govern operations prior to and during testing. There are several means by which risk can be minimized, as well as means by which the consequences of EED initiation can be mitigated.

- The weapon safety specification provides a complete listing of the EEDs in the weapon system and highlights those that are safety critical. It summarizes their design and firing characteristics. This list should be reviewed for completeness. EEDs in JTA instrumentation should also be listed and their sensitivities should be determined and documented.
- JTA testers are calibrated at least once every ninety days at Pantex to confirm that the power supplies are putting out the appropriate voltages and currents, and (if applicable) that the protection circuitry is shutting down the supplies when the programmed limits are exceeded.
- Tester and JTA connectors are routinely inspected for bent pins or foreign metallic material prior to making the connection. In some cases, the connectors are cleaned prior to each assembly.
- For JTA configurations that are deemed to have especially severe consequences if inadvertent initiation occurs (e.g., those that include insensitive high explosive), testing may be halted if lightning or static warnings are issued. Lightning is also an issue for instrumentation use in the in the field following a flight test. There must be adequate administrative controls that prevent inadvertent initiation of EEDs due to lightning when personnel are present. This should include procedures that do not allow personnel to be near the weapon when lightning is a threat.

- A fixture may be used on relevant JTA configurations to help prevent unit rotation if the spin rocket is inadvertently initiated; a net may be positioned behind the unit for JTA configurations that include a parachute.
- Signs should be posted during some levels of testing to warn personnel that they should not stand in front of or behind a test unit.
- For JTA configurations that are deemed to have especially severe consequences if inadvertent initiation occurs (e.g., those that include insensitive high explosive), they can be remotely tested.
- All administrative procedures that help to mitigate risk (ceasing operations during lightning, posting of warning signs, etc.) should be formally documented and followed carefully.
- Although containment of RF energy is not explicitly addressed in EP401575, it is an important personnel safety issue. The Product Specifications for testing at Pantex and the accompanying procedures should both be written to ensure that space caps are properly installed prior to RF transmission and should remain installed until transmissions cease.

Conclusion

Most of the designs and procedures described above have been used to reduce the risk of inadvertent initiation of EEDs during JTA testing at Pantex. It is recommended that they be considered during Phase 6.3 activities and when telemetry and/or tester redesign opportunities arise.

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